Potential Consequences of E-Cigarette Use: Is Youth Health Going Up in Smoke?

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14. ABSTRACT
The recent spike in popularity of electronic cigarettes (e-cigarettes) among America's adolescents may have significant health consequences. Such consequences would affect the Department of Defense's recruitable population, which is predominantly composed of adolescents and young adults. Using data from the National Youth Tobacco Survey (NYTS), we examine trends over time in the use of traditional tobacco and e-cigarettes. We also use NYTS data during the 2002-2006 period to predict the use of traditional cigarettes and chewing tobacco (chew) among NYTS respondents participating in the 2011-2014 survey waves. By comparing the accuracy of these predictions across e-cigarette users and nonusers, we shed light on the relationship between e-cigarette and traditional tobacco use. Specifically, we demonstrate that NYTS participants in the 2011-2014 waves who report having ever tried e-cigarettes are far more prone to using cigarettes and/or chew than the data from the 2002-2006 period predict. We also show that these youth smoke conventional cigarettes more frequently and intensely than expected. In stark contrast, 2011-2014 NYTS respondents who have not tried e-cigarettes are less prone to tobacco use than predicted, and they smoke less often/less intensely. One interpretation of these results is that e-cigarettes could be a "gateway drug" that will entice more youth to eventually smoke or chew—diminishing the overall health of the recruitable population.

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Abstract

The recent spike in popularity of electronic cigarettes (e-cigarettes) among America's adolescents may have significant health consequences. Such consequences would affect the Department of Defense's recruitable population, which is predominantly composed of adolescents and young adults. Using data from the National Youth Tobacco Survey (NYTS), we examine trends over time in the use of traditional tobacco and e-cigarettes. We also use NYTS data during the 2002-2006 period to predict the use of traditional cigarettes and chewing tobacco (chew) among NYTS respondents participating in the 2011-2014 survey waves. By comparing the accuracy of these predictions across e-cigarette users and nonusers, we shed light on the relationship between e-cigarette and traditional tobacco use. Specifically, we demonstrate that NYTS participants in the 2011-2014 waves who report having ever tried e-cigarettes are far more prone to using cigarettes and/or chew than the data from the 2002-2006 period predict. We also show that these youth smoke conventional cigarettes more frequently and intensely than expected. In stark contrast, 2011-2014 NYTS respondents who have not tried e-cigarettes are less prone to tobacco use than predicted, and they smoke less often/less intensely. One interpretation of these results is that e-cigarettes could be a "gateway drug" that will entice more youth to eventually smoke or chew—diminishing the overall health of the recruitable population.

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Executive Summary

Since their U.S. introduction around the beginning of 2007, electronic cigarettes (e-cigarettes) have dramatically increased in popularity, particularly among American adolescents.[1] This phenomenon has prompted a new but rapidly expanding literature on the causes and consequences of e-cigarette use; furthermore, policy-makers are struggling to understand how to develop well-designed regulations for these products. The Department of Defense (DOD), given its heavy reliance on the adolescent population for future manpower needs, should be especially concerned about how e-cigarette use will affect this group. This study draws on existing literature and publicly available data from the National Youth Tobacco Survey (NYTS) to address three fundamental research questions:

1. Are e-cigarettes harmful to one's health, and, if so, how do those negative effects compare with the damage done by traditional cigarettes?
2. What is the relationship between e-cigarette and traditional cigarette use? Specifically, do e-cigarettes serve as a substitute or a complement to regular cigarettes?
3. What is the level of e-cigarette consumption among those who would traditionally be nonsmokers, and are e-cigarettes a "gateway drug" for using traditional tobacco products?

In addition, we make recommendations aimed at improving DOD policies in this regard, and laying a foundation for future research efforts.

The NYTS is administered by the Centers for Disease Control and Prevention (CDC). It began in 1999 as a nationally representative survey of American adolescents in the 6th through 12th grades. It continues to the present day, though the latest year of data available on the CDC website[2] is 2014. The survey questionnaire explores exposure to various tobacco products, either indirectly (i.e., through secondhand smoke or advertising) or directly. Questions on e-cigarette use first appeared in the survey in 2011, and have reappeared in every annual wave since then.

[1] http://www.nytimes.com/2016/04/15/health/e-cigarettes-smoking-teenagers.html?_r=0.

[2] http://www.cdc.gov/tobacco/data_statistics/surveys/nyts/.

We use the 2002-2014 NYTS data to explore the relationship between e-cigarettes and two traditional tobacco products (cigarettes and chewing tobacco (chew)). We first examine trends in use over time and then produce summary statistics that describe the population of smokers, chewers, and e-cigarette users (or *vapers).* Next, we divide our data into two periods: (1) the 2002-2006 NYTS waves (the "before period") and (2) the 2011-2014 NYTS waves (the "after period"). E-cigarettes had not yet been introduced in the United States during the before period; therefore, these data provide us with the most recent information on adolescent tobacco use *in the absence of e-cigarettes.*

Using before-period data, we estimate logistic and multinomial logistic regression models aimed at predicting the use of traditional cigarettes and chew in the absence of e-cigarettes; these models then are used to predict behavior in the after-period (i.e., 2011-2014) NYTS respondents. By comparing our predictions with actual outcome data, we can determine how well our regression models perform at out-of-sample prediction, and whether e-cigarette use affects prediction accuracy. This exercise sheds light on the potential relationship between e-cigarette and traditional tobacco use, and it serves to motivate future research efforts. The results obtained through these empirical analyses are summarized in the paragraphs that follow.

As expected, the NYTS data indicate that traditional cigarette use among American adolescents has dropped precipitously in recent years, from 17 percent in 2002 to just 4 percent in 2014. Chew also has been tracked in all NYTS waves, with its use remaining relatively constant over the period (5 percent in 2002 vs. 4 percent in 2014). Although e-cigarette questions have only been asked since 2011, the data available indicate that vaping is rapidly expanding among American adolescents. In fact, although only 1 percent of respondents reported using e-cigarettes in 2011, about 9 percent did so in 2014 (a ninefold increase).

The summary statistics we generate provide a snapshot of the vaping population, and give us a sense of how these adolescents differ from traditional smokers, chewers, and nonusers. For example, we find that vapers are much older than non-users but are also slightly younger than NYTS respondents who report using traditional cigarettes and/or chew. Vapers are also more likely to be female, white, and Hispanic in comparison with nonusers, and they are far more likely to live with someone who smokes traditional cigarettes than are nonusers.[3]

Our predictive analyses reveal a number of interesting results. First of all, we find that e-cigarette use is more common among 2011-2014 NYTS respondents whom we predict to have a relatively high risk of smoking and/or chewing (based on before-

[3] All of the differences discussed here are statistically significant at the 5-percent level.

period data); in other words, adolescents who vape seem to be drawn disproportionately from the population of youth who are more likely to use traditional tobacco products in the first place. Having said this, we do find that a minority of vapers in the NYTS data are adolescents with a relatively low chance of using traditional tobacco products. This latter finding suggests that vaping may be spreading to parts of the youth population that would otherwise have very low exposure to tobacco products.

The logit and multinomial logit models we estimate (using before-period data) also perform quite differently when making out-of-sample predictions for vapers and nonvapers during the 2011-2014 period. In the latter case, our logit models substantially overestimate the number of traditional smokers among nonvapers. Furthermore, we predict that nonvapers smoke traditional cigarettes more frequently (i.e., on more days) and more intensely (i.e., more cigarettes per day) than is actually the case. These overestimates reflect the fact that traditional smoking has declined more rapidly among American adolescents in the last half-decade or so, and our regression models are based on data from a period (2002-2006) that predates this accelerated decline.

Given that our before-period logit and multinomial logit models fail to capture the relatively more rapid decline in traditional smoking that we see in the post-2006 period, it is especially surprising that the same models *underestimate* traditional cigarette use among vapers in the 2011-2014 period. In fact, 2,920 (46 percent) of the vapers in our after-period data used traditional cigarettes and/or chew at least once in the 30 days leading up to their interviews, which is more than 2.5 times the predicted number (1,134). Furthermore, our multinomial logit models substantially underestimate smoking frequency and intensity among vapers.

Several of these findings suggest that e-cigarettes may affect various outcomes of interest (e.g., propensity to smoke traditional cigarettes); unfortunately, e-cigarette use is not randomly assigned among NYTS respondents, which prevents us from making any definitive causal statements about the effects of e-cigarette use. Be that as it may, the results lend weight to the suggestion that adolescent e-cigarette use is concentrated among those who would have been at relatively high risk for tobacco use in the absence of e-cigarettes; however, the results also make clear that a minority of adolescent vapers would have otherwise been at low risk for tobacco use. In this sense, e-cigarette use does appear to have spread somewhat among American adolescents who would otherwise have not been likely to use tobacco products.

The other results are more difficult to interpret. One possibility is that vaping represents an addiction gateway that encourages traditional tobacco use, making e-cigarette users more likely to smoke and/or chew than we would otherwise expect. Furthermore, it could be that e-cigarettes and traditional cigarettes are complements, meaning that adolescent vapers smoke normal cigarettes more frequently and with greater intensity than they would if e-cigarettes were not available. However, it is also

possible that these results are driven by unobserved factors that affect e-cigarette use and traditional tobacco use, and that e-cigarettes have no causal effect on smoking and/or chewing behavior.

Our results suggest that e-cigarette use may have significant effects on DOD's recruitable population. However, in the absence of better data and improved identification (e.g., through a randomized control trial or quasi-experimental design), we cannot offer specific recommendations with regard to how DOD should regulate e-cigarettes. Instead, we feel that our literature review and empirical findings justify a number of recommendations focused on improving future research efforts and enhancing educational outreach. Specifically, we recommend that DOD (1) change DD Form 2807-2[4] to include questions about tobacco use (including specific questions about e-cigarettes), (2) explore options for monitoring tobacco use among servicemembers, (3) actively track regulatory changes related to e-cigarettes, and (4) play a leading role in disseminating educational materials pertaining to e-cigarettes.

[4] DD Form 2807-2 is the Accessions Medical Prescreen Report, completed during processing at the Military Entrance Processing Station.

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Glossary

AP	Acetyl Propionyl
AUC	Area Under the ROC Curve
CDC	Centers for Disease Control and Prevention
chew	Chewing Tobacco
DA	Diacetyl
DOD	Department of Defense
e-cigarette	Electronic Cigarette
FDA	Food and Drug Administration
MEPS	Military Entrance Processing Station
NYTS	National Youth Tobacco Survey
ROC	Receiver Operating Characteristic

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Introduction

Electronic cigarettes, or e-cigarettes, were invented in 2003 by Chinese pharmacist Hon Lik and were first marketed in the United States in late 2006 and early 2007 [1]. Originally intended as an aid for smoking cessation, the use of e-cigarettes has ballooned in recent years, particularly among American preteens and teenagers. In fact, data from the National Youth Tobacco Survey (NYTS) suggest that use has increased roughly fivefold among middle schoolers and more than tenfold among high schoolers between 2011 and 2015 [2].[5] Because of this increase, the Centers for Disease Control and Prevention (CDC) now identifies e-cigarettes as the most common tobacco product used by American middle and high school students [3].[6]

The rapid rise in youth e-cigarette use stands in stark contrast to the continuing decline in traditional smoking among young Americans, a phenomenon that has unclear implications for the health and readiness of the population of potential military recruits (almost all of whom are adolescents or young adults). On one hand, if e-cigarettes represent a healthier alternative to conventional smoking, a shift from traditional cigarettes to e-cigarettes suggests that the population of potential military recruits should become healthier over time. However, if e-cigarettes have negative health effects, and they are adopted by youth who would otherwise never have used traditional tobacco products, the average health of the recruitable population could decline over time. The chief of health promotion at the Air Force Medical Support Agency, Col. John Oh, has even acknowledged, "Not enough is known about the long-term safety of e-cigarettes to definitely state that they are safe [4]." Naturally, whether the health of military recruits improves or worsens over time is a question of central importance to policy-makers because healthier populations produce more effective fighting forces at lower cost.

Concerns about population health and military recruiting are not new; in fact, over the last several years, CNA has published several studies investigating the impact of

[5] From 2011 to 2015, middle schooler use of e-cigarettes grew from less than 1 percent to 5 percent, and high schooler e-cigarette use grew from 1.5 percent to 16 percent.

[6] The description of e-cigarettes as a "tobacco product" is controversial because tobacco is technically not an ingredient in e-cigarette liquids (though nicotine is). For regulatory purposes, however, the Food and Drug Administration (FDA) places e-cigarettes in this category.

obesity on recruiting and attrition, as well as barriers to tobacco cessation [5-8]. Human patterns of activity and consumption preferences are constantly changing, and it is imperative that the military identify and adapt to these changes to maintain readiness. E-cigarettes are simply the most recent example, and their alarming growth in popularity among the recruitable-age population demands a comprehensive examination of their use and effects.

Aside from concerns about the chronic health effects of e-cigarettes on the recruitable population, there are growing concerns in some circles that e-cigarette devices (which operate on lithium-ion batteries) suffer from quality-control issues and are consequently prone to failure (i.e., explosions and fires). A *Navy Times* article discusses recent injuries suffered by sailors due to e-cigarette explosions, a trend that may prompt the Navy to ban e-cigarette use altogether [9]. For this reason alone, the military may view e-cigarette adoption among the recruitable-age population as an undesirable development.

This study is motivated by three specific questions:

1. Are e-cigarettes harmful to one's health, and, if so, how do those negative effects compare with the damage done by traditional cigarette use?
2. What is the relationship between e-cigarette and traditional cigarette use? Do e-cigarettes serve as a substitute or a complement to regular cigarettes?
3. What is e-cigarette use like among those who would traditionally be non-smokers, and are e-cigarettes a gateway drug for traditional cigarettes?

Scientific research in this area is still developing, but significant progress has been made in answering these questions. We begin with a literature review documenting these efforts. Next, we use data from the NYTS to examine the growth in e-cigarette use among the U.S. adolescent population. We look at trends over time and then split our sample into two groups—before e-cigarettes (2002-2006) and after (2011-2014)—for predictive analysis.

Although we hope that this research will be useful for DOD policy-makers, the fact remains that none of the services collect data on e-cigarette use among new recruits, and e-cigarette use is currently inadequately tracked among existing servicemembers.[7] This lack of data is a serious obstacle to understanding how e-cigarettes affect the health of the military population (especially new recruits), and it prevents the formulation of effective policy. As a result, we conclude by

[7] We are aware of a single question in the DOD Health Related Behaviors Survey that asks about e-cigarette use. However, this question fails to capture e-cigarette use in sufficient detail, and the survey itself is only taken by a random sample of active-duty military personnel.

recommending changes to DD Form 2807-2[8] that are aimed at measuring tobacco use in general (and e-cigarette use in particular) among military accessions.

[8] DD Form 2807-2 is the Accessions Medical Prescreen Report.

Literature Review

Health effects of electronic cigarettes

Perhaps the most fundamental question about e-cigarettes is whether they actually harm one's health and, if so, to what extent. Unfortunately, these devices have not been in use long enough to provide a definitive answer as to the long-term health effects, but some preliminary evidence exists. The original intention of e-cigarettes was to provide a safer alternative to traditional smoking, and e-cigarette marketing makes the relative safety of vaping (vs. smoking) a focal point of its message. According to an online survey whose results were published in 2013, e-cigarette users generally believe that traditional smoking is more dangerous and more addictive than e-cigarette use. However, survey respondents did not usually conclude that e-cigarettes were perfectly safe; over 80 percent agreed that the practice has at least some harmful effects [10]. A similar study found that those experimenting with e-cigarettes were more likely to believe that vaping helps to reduce or eliminate traditional smoking and that e-cigarettes represent a safer alternative [11].

Although researchers cannot yet fully determine the costs and benefits of e-cigarette use, there is ample evidence to reject the belief that e-cigarettes are a completely harmless alternative to smoking. First of all, most (though perhaps not all) e-cigarettes contain nicotine[9], which has long been known to be an addictive chemical. In fact, a recent study found that some e-cigarettes may induce higher nicotine blood levels than are generated by traditional smoking, which may be associated with higher addiction rates [14]. In a separate study, researchers found huge variation in the amount of nicotine present in different e-cigarette liquids, including samples that had highly toxic (and potentially lethal) levels [15]. Fortunately, there is not much indication that nicotine levels in e-cigarettes *must* inherently be high; rather, this finding suggests a significant lack of quality control in the e-cigarette industry.

[9] This is a disputed point. Some e-cigarette liquids are labeled as nicotine-free and, in a recent survey, most adolescents reported that the liquid they used contained only flavoring [12]. However, there is evidence to suggest that even so-called nicotine-free e-cigarettes actually contain detectable nicotine levels [13].

Recent regulations announced by the FDA in May of 2016 may go a long way in solving these issues since (among other conditions) they require manufacturers to list ingredients, and they mandate premarket FDA reviews [16].

Of course, the addictive potential of e-cigarettes is of greater concern if use is associated with adverse health effects. To date, several studies have suggested examples, especially as a result of toxic chemicals often present in e-cigarette liquids. For instance, many e-cigarette liquids contain diacetyl (DA), which is known to cause health problems (including bronchiolitis obliterans, a life-threatening condition) [17]. A 2015 study found that nearly three-quarters of e-cigarette samples studied contained DA or acetyl propionyl (AP), another chemical known to cause respiratory problems [18]. Further, a 2014 study published in *Tobacco Control* demonstrates that more children are using e-cigarettes and that this increased use is associated with more visits to poison centers [19]. Other health concerns associated with e-cigarettes (including the presence of other toxins, particulate matter, etc.) are summarized in a 2014 review published in the journal, *Circulation* [20].

Substitution between traditional tobacco use and e-cigarettes

In short, there is clear evidence to reject the notion that e-cigarettes are harmless, but this does not preclude the possibility that they represent a safer alternative to traditional smoking. In fact, in a 2014 review of the literature on e-cigarette risk and safety, the authors conclude that e-cigarettes are far less harmful and that future research and more stringent quality-control efforts will make their use even safer [21]. This viewpoint is not uncommon; various experts and organizations have adopted the attitude that any harm caused by e-cigarettes is more than offset by its potential to reduce traditional smoking [22-23]. It seems that this view is shared by a large percentage of e-cigarette users, who often motivate their adoption of the product as an attempt to quit smoking entirely, or at least reduce their consumption of traditional cigarettes [24]. Even so, the value of e-cigarettes as a tool to improve the health of potential military recruits depends critically on whether traditional tobacco users in this group actually adopt e-cigarettes to partially or fully offset their tobacco use.

The literature provides numerous resources with regard to this question. For example, a 2010 study finds that the use of a particular e-cigarette brand is associated with reduced desire to smoke traditional cigarettes in the short term [25]. Similarly, work published in 2013 found that e-cigarette use among smokers with no

intention to quit at baseline led to significant and enduring reductions in cigarette use, even when the e-cigarette liquid used contained no nicotine.[10] In the latter study, e-cigarette liquids of varying nicotine concentrations were prescribed to three groups of smokers over a period of 12 weeks. Participants were evaluated over 12 months and, in all three groups, significant and similar reductions in cigarette consumption were found. [26].

Additional evidence on this substitution between e-cigarettes and traditional tobacco products (especially cigarettes) abounds, though the conclusions are sometimes conflicting. For instance, a longitudinal internet survey of e-cigarette users conducted between 2011 and 2013 found that most respondents were former smokers (72 percent) and that recidivism to traditional smoking was fairly rare among those who reported being former smokers at baseline. Furthermore, a substantial minority of people reporting dual use[11] at baseline had discontinued traditional smoking by the time that they had completed their one-month (22 percent) or one-year (46 percent) follow-up [27].[12] Data from Wave 8[13] of the International Tobacco Control Four-Country Survey also suggest that a high fraction of e-cigarette users are motivated by perceptions that e-cigarettes are less harmful than traditional smoking and a desire to reduce or eliminate their consumption of traditional cigarettes [28]. In addition, at least one cross-sectional population study supports the value of e-cigarettes as a cessation aid because it finds that people attempting to quit smoking without professional help were more likely to succeed [29].

Despite these hopeful signs, significant disagreement persists as to the effectiveness of e-cigarette use in smokers' efforts to reduce traditional tobacco use. This is especially true when discussing complete smoking cessation since several studies have found that e-cigarettes are ineffective in this regard. For example, a 2013 study in the *American Journal of Public Health* concludes that, although tobacco alternatives (such as e-cigarettes) hold an obvious attraction for traditional smokers who are trying to quit, there is no evidence that these devices are actually associated with smoking cessation [30]. A similar study published in the following year

[10] Both of the studies discussed here used randomized control designs of some kind, which allows the results to be interpreted causally.

[11] Dual use is defined as the daily use of e-cigarettes, together with at least occasional (and perhaps daily) use of conventional cigarettes.

[12] Results from this sample are likely to be biased as a result of how the data were collected. Specifically, respondents were enrolled via websites dedicated to e-cigarettes and smoking cessation; since the people frequenting these websites are more likely to be former smokers, and perhaps more likely to have experienced success in smoking cessation with e-cigarettes, their experiences may not accurately represent the experiences of e-cigarette users overall.

[13] Wave 8 data were collected between July 2010 and June 2011.

concluded that e-cigarette use at baseline was not significantly associated with reporting smoking cessation (or even a reduction in conventional cigarette use) during a one-year follow-up [31].

E-cigarette use among traditional nonsmokers

A critical assumption in the foregoing argument is that e-cigarettes will only be used by current smokers as a cessation aid, as opposed to a broader population of people. A recent study found that some reasons that youth initially try e-cigarettes are especially correlated with continued use, including (a) the low cost relative to conventional cigarettes, (b) the ability to use e-cigarettes anywhere, and (c) the ability to quit smoking traditional cigarettes [32]. All of these reasons suggest that chronic e-cigarette users may primarily be people who would otherwise have used traditional tobacco products (or used them more frequently). However, if e-cigarettes also are adopted in large numbers by those who would otherwise have never used any traditional tobacco product (or would have used those products less), then the adverse health effects suffered by that set of people are a new and troubling phenomenon. In this study, we are particularly concerned that e-cigarette use within the population of potential military recruits is not confined to current or former users of traditional tobacco products. This issue raises two questions:

1. How common is e-cigarette use among people who have never smoked traditional cigarettes?

2. Are e-cigarettes a gateway drug to traditional cigarette use?

Generally speaking, recent evidence with regard to the first question suggests that adults who have ever tried or who currently use e-cigarettes are very likely to be current or former smokers. Conversely, adult never-smokers rarely report having tried e-cigarettes and are very unlikely to report currently using them [33]. That said, there is much more evidence to suggest that youth who have never tried traditional cigarettes are experimenting with e-cigarettes and that this experimentation might ultimately lead to conventional tobacco use.

A piece published in the *Harvard Business Review* in April 2014 poses a simple question: are e-cigarettes displacing the tobacco market, or are they forming an entirely new market, including people who would have never smoked before? Although it is clear that a significant fraction of e-cigarette use is displacing traditional tobacco use, there is increasing evidence that youth who have never smoked are trying e-cigarettes [34]. For example, a survey of Polish youth conducted in 2010-2011 and again in 2013-2014 found that the fraction of never-smoked

adolescents who had tried e-cigarettes increased from 1.6 percent to 7.0 percent, a more than fourfold increase [35]. Similar studies in other countries have reached a similar conclusion: although e-cigarette use among adolescents is still dominated by current and former tobacco-product users, the fraction of never-smoked youth who are trying e-cigarettes continues to rise [36].

The apparent growth of e-cigarette use among never-smoked adolescents may represent an important health concern for the population of potential military recruits, especially if e-cigarette use serves as a gateway to traditional tobacco products [37]. Lamentably, several studies suggest that this is the case. For example, a paper published in 2016 reports the results of a cross-sectional survey of 2,309 high school students. Eighteen percent of the sample reported having tried e-cigarettes and never using traditional cigarettes. These people were significantly more likely to express a willingness to try conventional cigarettes, which strongly predicts future smoking behavior [38]. Similarly, a 2014 study found that the number of never-smoked youth using e-cigarettes tripled between 2011 and 2013, and that these people were more likely to intend to smoke traditional cigarettes at some point in the future [39]. Finally, a 2016 study using data from the 2012 NYTS wave finds that adolescents who have never smoked (or have only experimentally smoked[14]) are significantly more likely to intend to smoke traditional cigarettes in the future if they have tried e-cigarettes. The same study finds that current adolescent smokers are less likely to intend to quit smoking if they also use e-cigarettes [40].

There are also longitudinal studies that suggest that e-cigarette use among youth who have never smoked is a gateway to traditional smoking. A 2015 study followed 694 participants (16- to 26-year-olds who had never smoked) between October 2012 and May 2014 and found that e-cigarette use at baseline was associated with reporting having smoked conventional cigarettes in the follow-up survey [41]. Another study (of adolescents who reported having never used combustible tobacco products at baseline) found that e-cigarette use at baseline is associated with an increased probability of using a wide variety of combustible tobacco products, as determined by 6-month and 12-month follow-up surveys [42]. These findings may reflect evidence that nicotine itself is a gateway drug,[15] as suggested by a recent study in the *New England Journal of Medicine* [43].

[14] In this study, survey respondents are defined as having experimented with traditional cigarettes if they (1) have smoked a cigarette before, (2) have smoked fewer than 100 cigarettes in their lifetime, and (3) have not smoked a cigarette in the past 30 days.

[15] The authors define a gateway drug more broadly (i.e., as "a drug that lowers the threshold for addiction to other agents").

Despite some suggestive evidence that e-cigarette use can drive future use of traditional tobacco products, many skeptics remain. For example, a 2016 opinion piece in *Forbes* points out that the use of conventional cigarettes among America's youth continues to decline, even as the use of e-cigarettes in the same population has skyrocketed [44]. The author points out that studies such as those cited above suffer from a fundamental selection problem since "it may simply be that the sort of teenagers who are inclined to try vaping are also inclined to try smoking, and that they try the former first because it smells and tastes better and causes less discomfort."

Summary

In the introduction, we posed three questions that are fundamental to understanding the effect that e-cigarettes may have on the recruitable population:

1. Are e-cigarettes harmful to one's health, and, if so, how do those negative effects compare with the damage done by traditional cigarette use?

2. What is the relationship between e-cigarette and traditional cigarette use? Specifically, do e-cigarettes serve as a substitute or a complement to regular cigarettes?

3. What is the level of e-cigarette use among people who would traditionally be non-smokers, and are e-cigarettes a gateway drug for cigarettes?

The first of these questions is the most straightforward: yes, e-cigarettes have demonstrable negative health consequences in the short term. Those effects, however, are mild compared with those of traditional tobacco products. It is important to note that the long-term consequences of e-cigarette use are poorly understood since these devices have not been around long enough for conclusive evidence to be obtained. Consensus on the final two questions is more elusive; experts offer many competing arguments. In fact, the lack of agreement in these areas has been one of the chief motivating factors for the current study.

Data

National Youth Tobacco Surveys

The data used in the analyses were drawn from seven[16] annual waves of the NYTS, a nationally representative survey conducted by the CDC. The focus of the survey is on adolescents in grades 6 through 12, and it includes many questions related to the use of various tobacco products. Basic demographic information (e.g., age, gender, race, and ethnicity) also are collected.

Beginning in 2011, the CDC added several questions to the NYTS concerning the use of e-cigarettes, which were introduced in the United States in late 2006/early 2007. Table 1 compares the demographic characteristics of adolescent tobacco users before the introduction of e-cigarettes (i.e., 2002-2006, the "before period") and the characteristics of the same population after e-cigarettes became available (i.e., 2011-2014, the "after period").[17] In addition, Table 1 summarizes intersample differences in those demographic characteristics, showing statistically significant differences highlighted in green if there is an increase and in red if there is a decrease in the proportion of the sample that is in that category from the before e-cigarettes sample (2002-2006) to the after e-cigarettes sample (2011-2014). Table 1 shows that the sample of youth are in higher grade levels, less female, less white, and more Hispanic in the 2011-2014 population than in the 2002-2006 population. In addition, fewer youth are living with smokers in the 2011-2014 period than in the 2002-2006 period. Therefore, it is important to control for these demographic characteristics in any subsequent analysis in which we compare the before and after e-cigarette samples.

[16] This includes the 2002, 2004, 2006, 2011, 2012, 2013, and 2014 waves, but excludes the 2009 wave. Before 2011, the survey was not always conducted in every year.

[17] Although the NYTS was conducted in 2009, no questions about e-cigarette use were asked, even though the devices had been available in the U.S. for about two years. Because we cannot observe e-cigarette use in NYTS respondents in this wave, we drop it from our analyses.

Table 1. Summary statistics for the full sample before and after the introduction of e-cigarettes[a,b]

Full sample[c]	2002-2006	2011-2014	Difference
Grades 6-8	45.1%	43.4%	-1.7%
Grades 9-10	30.3%	29.9%	-0.4%
Grades 11-12	24.6%	26.7%	2.1%
Female	51.5%	49.9%	-1.6%
Asian	4.6%	6.2%	1.6%
Black	17.7%	21.2%	3.5%
Pacific Islander	2.0%	2.7%	0.7%
Native American	4.6%	6.3%	1.7%
White	77.4%	73.1%	-4.3%
Hispanic	6.2%	15.9%	9.7%
Lives with smoker	40.5%	31.3%	-9.2%
N	60,966	67,431	

Source: CNA generated from the 2002, 2004, 2006, 2011, 2012, 2013, 2014 NYTS waves.

a. Differences highlighted in green represent a statistically significant (p ≤ .05) increase in the proportion of the sample that is in that category from the before e-cigarettes sample (2002-2006) to the after e-cigarettes sample (2011-2014).

b. Differences highlighted in red represent a statistically significant (p ≤ .05) decrease in the proportion of the sample that is in that category from the before e-cigarettes sample (2002-2006) to the after e-cigarettes sample (2002-2014).

c. Sample weights are used to characterize a nationally representative sample of youth.

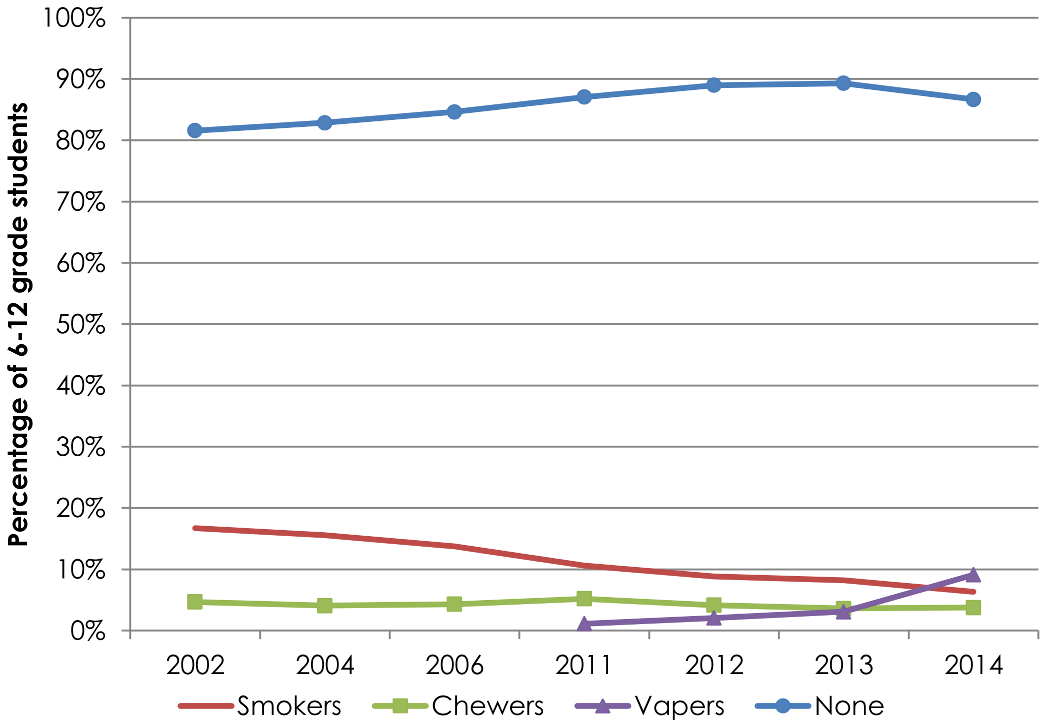
The results produced using these data will focus on time trends, summary statistics, and other statistical analyses aimed at identifying correlations in the data (rather than making causal inferences). Given that e-cigarettes burst on the scene so quickly, regulatory agencies still are struggling to understand the consequences of e-cigarette use; consequently, we are unaware of any policy and/or regulatory interventions that offer a "natural experiment"[18] through which the causal effect of e-cigarette use on a given outcome can be identified. Although this limits the implications of our findings for policy-makers, we still develop a solid foundation on which future research efforts may build.

[18] An excellent example would be if e-cigarettes became legal on a state-by-state basis over time. In such a case, we could use interstate variation in e-cigarette legality (which is presumably exogenous) to identify any causal effects of interest, such as the effect of e-cigarette use on one's consumption of conventional cigarettes.

Time trends of youth tobacco product use

Youth tobacco use habits have changed substantially over the past two decades. Using 2002-2014 NYTS data, Figure 1 depicts the percentages of grade 6-12 students who had reported using different types of tobacco products in the last 30 days. Over that time period, the data indicate that there has been a steady downward trend in the percentage of youth who reported that they had smoked traditional cigarettes in the last 30 days *(smokers)*, which was around 17 percent in 2002 and only around 4 percent by 2014. Meanwhile, over the same time period, the percentage of youth who reported that they had chewed tobacco in the last 30 days *(chewers)* hovered between 3 and 5 percent.

Figure 1. Percentages of grade 6-12 students using different tobacco products in the last 30 days



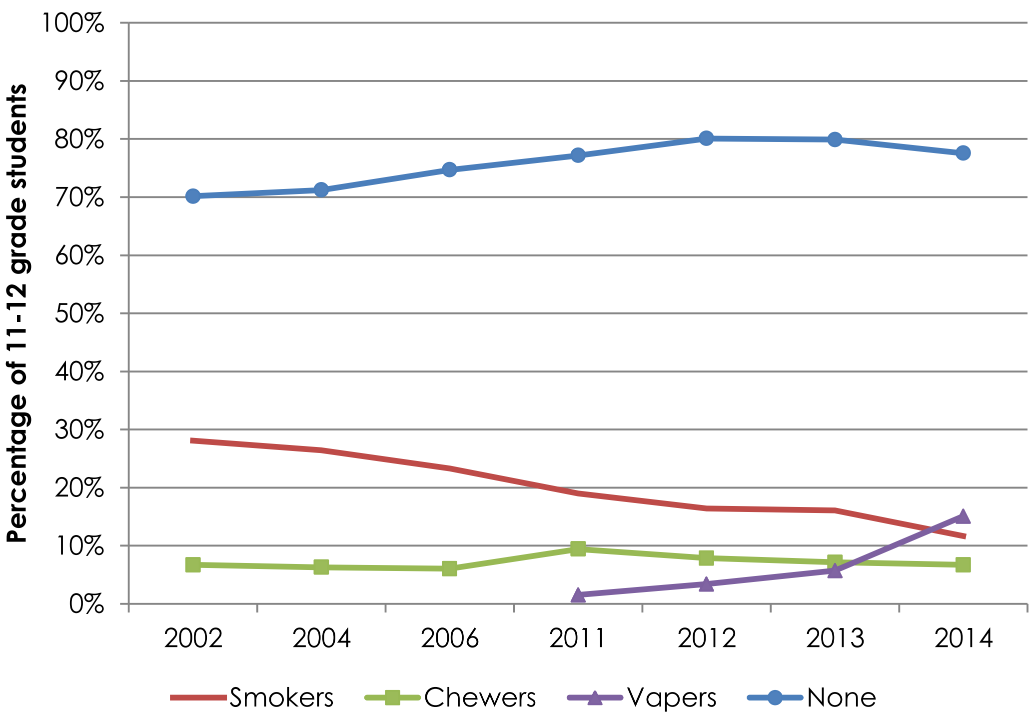
Source: CNA-generated chart from the 2002, 2004, 2006, 2011, 2012, 2013, and 2014 NYTS waves.

After the introduction of e-cigarettes, there was quick growth in the percentage of youth who reported that they had used e-cigarettes in the past 30 days *(vapers)*,

which increased from 1 percent in 2011 to 9 percent by 2014—surpassing the percentages of both reported smokers and chewers. In addition, there was an upward trend from 2002 to 2013 in the percentage of youth who said that they had not used any tobacco products in the last 30 days (82 percent in 2002 vs. 89 percent in 2013). However, the percentage of *nonusers* fell in 2014 to 86 percent, which was the same year that there was a spike in the percentage of vapers.

As seen in Figure 2, similar patterns emerge when the sample is restricted to 11th and 12th grade students.[19] However, the percentages of smokers, chewers, and vapers in each year are higher for this older sample of students, when compared with the entire population. For example, in 2014, 7 percent of the sample were chewers, 12 percent were smokers, and 15 percent were vapers.

Figure 2. Percentages of grade 11 and 12 students using different tobacco products in the last 30 days

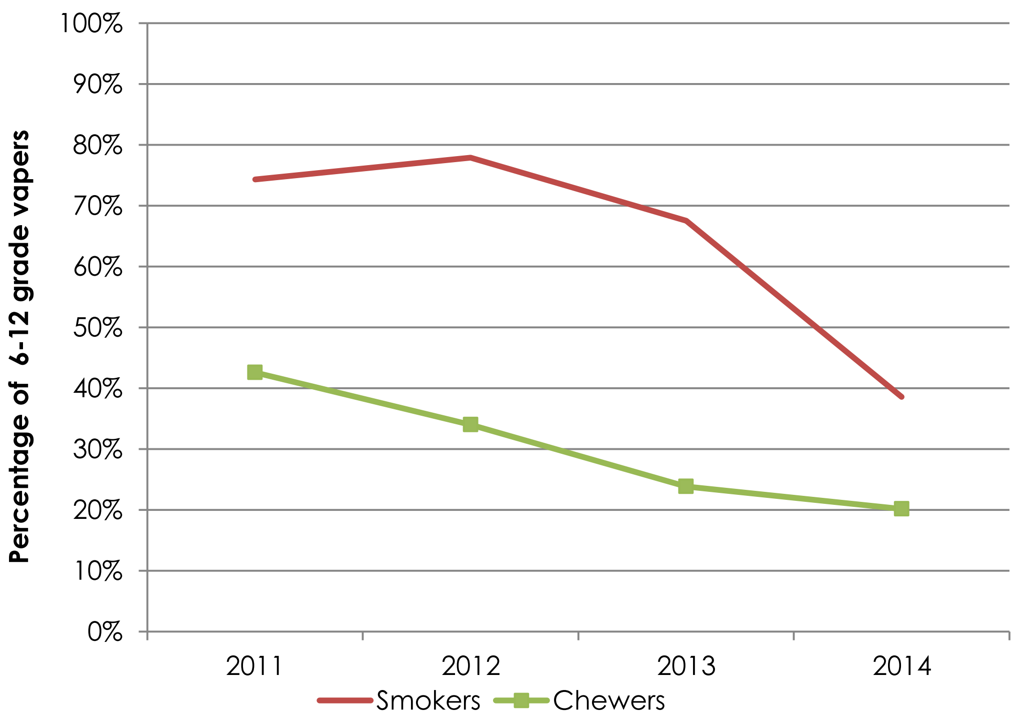


Source: CNA-generated chart from the 2002, 2004, 2006, 2011, 2012, 2013, and 2014 NYTS waves.

[19] We expect that this set of students is more similar to the DOD recruitable population than the full NYTS sample.

Figures 3 through 5 examine the percentage of students using multiple tobacco products in the past 30 days from the 2011-2014 period. Of interest, Figure 3 indicates that the percentage of vapers who were also smokers initially increased from 74 percent in 2011 to 78 percent in 2012 and then declined to 39 percent by 2014. There are several potential explanations for this decline in the proportion of vapers who were also smokers, none of which can be confirmed by simply examining these summary data. First, it might be that between 2012 and 2014 more smokers were moving away from using traditional cigarettes to exclusively using e-cigarettes. Alternatively, it could be that more nonusers were taking up e-cigarettes, thereby diluting the percentage of those smoking and vaping simultaneously. Another explanation could be that the youth population in the sample was changing over this time period, which could, in turn, affect the percentages in each of these categories. As also observed in Figure 3, there is a similar decline in the percentages of vapers who were also chewers from 2011 to 2014, with 43 percent of vapers also chewing in 2011 and only 20 percent of vapers also chewing by 2014.

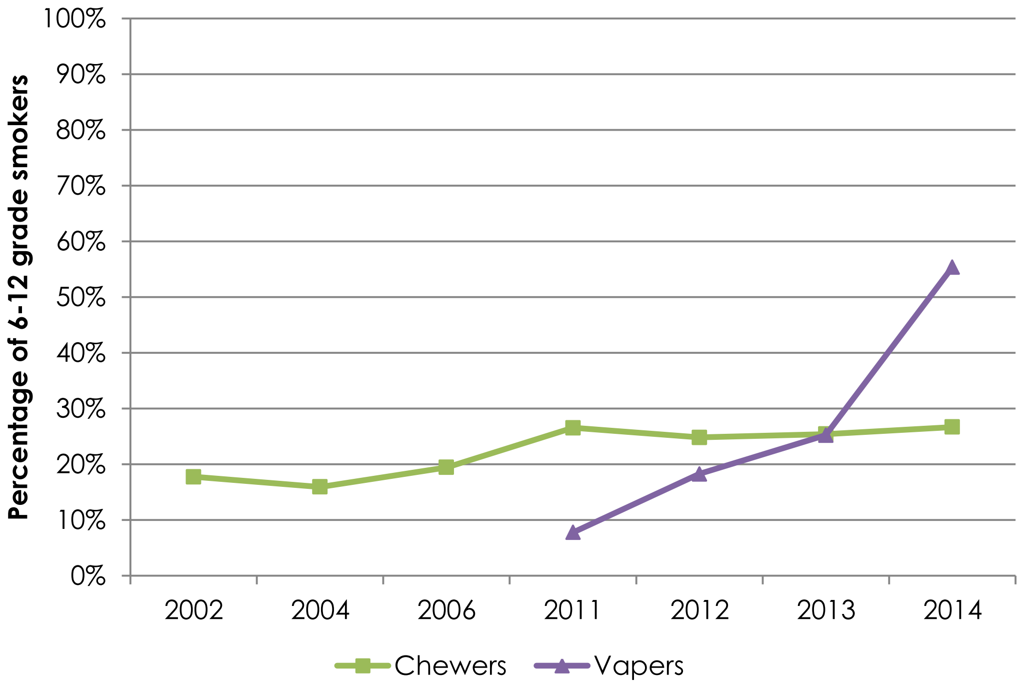
Figure 3. Percentages of 6-12 students who have vaped in the last 30 days and also have smoked and/or chewed in the past 30 days



Source: CNA-generated chart from the 2011, 2012, 2013, and 2014 NYTS waves.

Figure 4 reports the percentages of smokers who were also chewing and vaping. After the introduction of e-cigarettes, there is a continual increase in the percentage of smokers who were also vapers. The most drastic increase occurred between 2013 and 2014, when this proportion increased by 30 percentage points from 25 percent to 55 percent. By comparison, the percentage of smokers who were also chewers only increased by 9 percentage points from 2002 to 2014, from 18 percent to 27 percent.

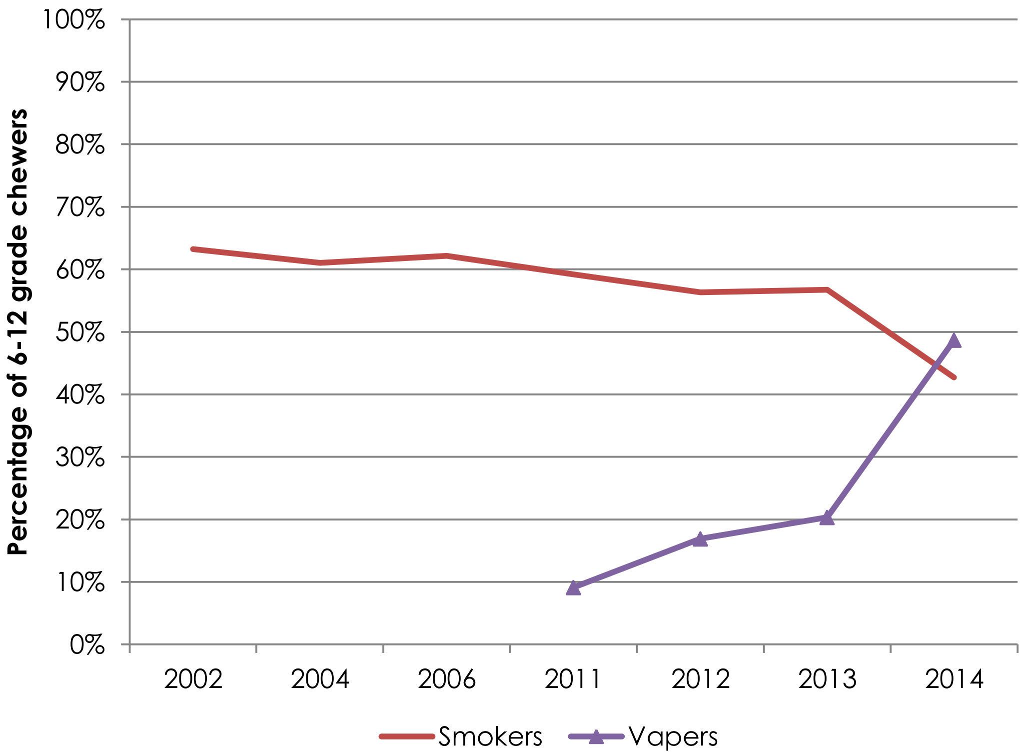
Figure 4. Percentages of grade 6-12 students who have smoked in the last 30 days and also have chewed and/or vaped in the past 30 days



Source: CNA-generated chart from the 2002, 2004, 2006, 2011, 2012, 2013, and 2014 NYTS waves.

Figure 5 displays similar patterns for the percentages of chewers who were also vapers during this time period. There is a gradual increase in this percentage from 2011 to 2013, with a more drastic increase occurring from 2013 to 2014 when the percentage of chewers who were also vapers rises from 20 percent to 49 percent. Meanwhile, the percentage of chewers who were also smokers declines by 14 percentage points from 2013 to 2014—from 56 percent to 42 percent.

Figure 5. Percentages of grade 6-12 students who have chewed in the last 30 days and also have smoked and/or vaped in the past 30 days



Source: CNA-generated chart from the 2002, 2004, 2006, 2011, 2012, 2013, and 2014 NYTS waves.

In addition to these time trends, we examine the demographic characteristics of the vaper population in the 2011-2014 period and report how they compare with smokers, chewers, and non-users during the same time period. Table 2 reports the demographic summary statistics for each of these groups and the differences in the demographic percentages of each of the different groups as compared with vapers.

Table 2 shows that a statistically significant higher percentage of vapers were in grades 11-12, were female, white, and Hispanic, and lived with smokers when compared with the full sample of NYTS participants from 2011 to 2014. Furthermore, when vapers are compared with smokers, chewers, and nonusers, the demographic characteristics of vapers most closely resemble those of smokers.

Table 2. Demographic characteristics of tobacco-product users and non-tobacco-product users from 2011-2014[a,b,c]

Demographics	Vapers	Smokers		Chewers		Nonusers		Full sample	
	Proportion of vapers	Proportion of smokers	Difference from vapers	Proportion of chewers	Difference from vapers	Proportion of non-users	Difference from vapers	Proportion of full sample	Difference from vapers
Grades 6-8	17.5%	15.5%	-2.0%	15.3%	-2.1%	47.0%	29.6%	43.4%	25.9%
Grades 9-10	37.7%	35.0%	-2.7%	35.0%	-2.7%	29.1%	-8.6%	29.9%	-7.8%
Grades 11-12	44.9%	49.5%	4.7%	49.7%	4.8%	23.9%	-21.0%	26.7%	-18.1%
Female	51.5%	48.8%	-2.6%	46.2%	-5.3%	50.1%	-1.4%	49.9%	-1.5%
Asian	5.5%	4.1%	-1.4%	3.9%	-1.6%	6.5%	1.1%	6.2%	0.8%
Black	16.2%	16.9%	0.7%	10.8%	-5.3%	21.9%	5.7%	21.2%	5.0%
Pacific Islander	3.1%	3.3%	0.2%	3.6%	0.5%	2.6%	-0.5%	2.7%	-0.4%
Native American	8.5%	7.5%	-1.0%	6.6%	-2.0%	6.1%	-2.4%	6.3%	-2.3%
White	80.3%	79.7%	-0.6%	86.7%	6.4%	72.1%	-8.2%	73.1%	-7.2%
Hispanic	20.2%	17.3%	-2.8%	13.4%	-6.7%	15.8%	-4.4%	15.9%	-4.3%
Lives with a smoker	51.1%	56.9%	5.8%	47.3%	-3.8%	28.5%	-22.6	31.2%	-19.9%
N	2,641	5,657		2,609		59,495		67,431	

Source: CNA-generated table from the 2011-2014 NYTS waves.

a. Cells highlighted in green represent a statistically significant (p ≤ .05) and higher proportion of youth in that category when compared with vapers in that category.

b. Cells highlighted in red represent a statistically significant (p≤.05) and lower proportion of youth in that category when compared with vapers in that category.

c. Sample weights are used to characterize a nationally representative sample of youth.

In addition, we estimate a logit model to determine whether youth with certain demographic characteristics are more or less likely than other youth to have ever tried vaping. Specifically, we estimate the likelihood that a youth has ever vaped given the following covariates: (1) survey year,[20] (2) gender, (3) Hispanic status, (4) race, (5) grade level, (6) being old or young for grade level,[21] and (7) living with someone who smokes. All observations in these regressions are weighted by NYTS-calculated sample weights.[22]

Results from this logit estimation are found in Table 3. This model estimates that those in later survey years, who are Hispanic or Native Americans, are in a higher grade, are old for their grade, or who live with a smoker are more likely to have ever-vaped than those in the comparison group.[23] Those who are black or Asian, or who are young for their grade are less likely to have ever vaped than those in the comparison group. The magnitudes of the estimates in the table can be interpreted as percentage point changes in the likelihood that someone has ever-vaped. For example, being Hispanic increases the likelihood that a person has ever vaped by 1 percentage point.

[20] Survey year is modeled as a linear time trend.

[21] We define "young for grade level" as being younger than the modal age in one's grade level; similarly, "old for grade level" is defined as being over the modal age in one's grade level. For example, the modal age for 6th grade is 12 years old, so any 6th grader 11 years old or younger is young for grade level, and any 6th grader 13 years old or older is old for grade level.

[22] These weights are meant to account for the fact that some types of students are more likely to appear in the sample. Each respondent is weighted (with some adjustments) by the inverse of the probability that they were included in the sample. Thus, respondents who had a high probability of being selected for the survey receive less weight, and those who had a low chance of being selected receive more weight.

[23] The comparison group is made up of 6th graders, in survey year 2011, who are non-Hispanic, are white, are average age for their grade, and do not live with a smoker.

Table 3. Estimated percentage point changes in the likelihood that participants ever vaped

Ever vaped[a,b]	
Variables	**Percentage point changes**
Survey Year	0.05**
Male	-0.004
Hispanic	0.01**
Black	-0.04**
Asian	-0.05**
Native American	0.02**
Pacific Islander	0.001
7th Grade	0.05**
8th Grade	0.08**
9th Grade	0.12**
10th Grade	0.15**
11th Grade	0.17**
12th Grade	0.18**
Young for Grade	-0.02**
Old for Grade	0.02**
Live with Smoker	0.08**
N	67,431
AUC[c]	0.79

Source: CNA-generated table from NYTS 2011-2014 data.

a. Significance levels: * = p ≤ 0.05, ** = p ≤ 0.01.

b. Sample weights are used to characterize a nationally representative sample of youth.

c. AUC stands for area under the Receiver Operating Characteristic (ROC) curve. The AUC measure can take any value between 0 and 1, and is commonly used to express the predictive power (at an individual level) of logit models. In some disciplines, this is referred to as the C-statistic.

However, comparing these demographic characteristics and examining these logit estimates alone will not answer the question of whether the act of vaping makes someone more or less likely to smoke traditional cigarettes or chew tobacco. We will explore these questions further in the following sections.

Predictive Analysis: Methodology

As discussed in the introduction, we do not have access to any plausible identification strategy (random assignment of e-cigarette use, natural experiments, etc.) that would allow us to measure the causal effect of e-cigarette use on outcomes of interest (e.g., conventional tobacco use). As a result, the results presented in this section do not allow one to reach any definitive conclusions about the effects of using e-cigarettes.

The NYTS's relatively long duration does allow for some analyses that are revealing and may motivate future research. As discussed in the data section, the NYTS includes several annual waves conducted before the introduction of e-cigarettes in the United States (2002, 2004, and 2006), a time period in our data we collectively refer to as the before period. In each annual wave since 2011, the NYTS has asked question about e-cigarette use (in addition to questions about traditional tobacco products). We therefore refer to 2011-2014 as the after period since it represents a time during which (1) e-cigarettes were available to American adolescents and (2) e-cigarette users could be identified in the NYTS. As we will demonstrate, using data from the before period to make predictions about behavior in the after period can shed light on the relationship between e-cigarettes and traditional tobacco products.

Predicting cigarette/chew use

Using data from the before period, we can estimate the probability of several outcomes of interest in an environment where e-cigarettes were unavailable as an alternative. The outcomes we investigate follow:

1. Having only smoked in the past 30 days
2. Having only chewed in the past 30 days
3. Having smoked and chewed in the past 30 days
4. Having neither smoked nor chewed in the past 30 days
5. Having never smoked or chewed

We use the same variables as we used in the previous section for the logit regression models in this section to model the probability of these five outcomes. Again, the outcomes are modeled as a function of (1) survey year, (2) gender, (3) Hispanic

status, (4) race, (5) grade level, (6) being old or young for grade level, and (7) living with someone who smokes. All observations in these regressions are weighted by NYTS-calculated sample weights.

Having estimated logistic regressions using data from the before period, we then can use these results to *predict* the same outcomes in the after period (i.e., the 2011-2014 NYTS waves). Of course, we also observe actual outcomes during the after period, making it possible to determine how well our logit models (based on before-period data) perform in the after period.

Table 4 illustrates this idea with a simple example. Suppose one uses the before-period data to estimate the probability that an NYTS respondent is a "smoker";[24] one then could use the results of that estimation to predict the number of smokers among a set of NYTS respondents interviewed during the after period. Table 4 considers 10 hypothetical after-period respondents. Note that columns 1 through 8 provide demographic details for each respondent, and that these details are used to construct the variables used in the before-period estimation. Column 8 reports *predicted probabilities*, which tell us how likely each person is to be a smoker. For example, the first respondent has a predicted probability of 0.06, meaning that we assign this person a 6-percent chance of being a smoker. Equivalently, we might say that the first respondent represents 0.06 smokers, the second respondent represents 0.25 smokers, and so on. Under this interpretation, the sum of fitted values (1.94) tells us how many smokers we should expect to find among these 10 after-period respondents, based on a logit model estimated using before-period data.

In the paragraph above, we discussed (1) estimating a logit model for the probability of smoking using data from the before period, (2) using the output of that model to generate predicted probabilities for NYTS respondents in the after period, and (3) summing predicted probabilities to estimate how many people in a given set of after-period NYTS respondents will be smokers. Of course, whether an NYTS respondent in the after period is a smoker is known since they answer questions about their tobacco use. Column 9 reveals that 2 of the 10 hypothetical NYTS respondents in Table 4 actually report being smokers, suggesting that the logit model based on before-period data (which predicted we would find 1.94 smokers in this set of 10) does a fairly good job of predicting smoking behavior in the after period *on an aggregate level*. Our focus on aggregate predictions is an important point: the variables to which we have access provide limited predictive power at an individual level, making it hard for us to identify whether a specific survey respondent is at high risk (i.e., > 50 percent probability) for the outcome we are trying to predict.

[24] A smoker is defined as having smoked in the last 30 days.

Table 4. Example of predicting smoking probabilities in after-period data, based on before-period logit models

ID #	Year	Gender	Age	Grade	Race	Hispanic	Lives with smoker	P(Smoker)	Smoker
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1	2011	male	12	6	white	no	no	0.06	no
2	2011	male	17	12	white	yes	yes	0.25	no
3	2012	female	15	10	black	no	yes	0.12	no
4	2014	female	16	10	asian	no	no	0.17	no
5	2013	female	18	12	white	yes	no	0.27	yes
6	2014	male	13	8	asian	no	no	0.19	no
7	2012	female	16	11	black	no	no	0.18	no
8	2011	male	14	9	black	no	yes	0.23	no
9	2014	male	17	11	white	no	yes	0.29	yes
10	2013	female	15	9	white	yes	no	0.18	no
Sum								1.94	2

Source: Hypothetical example is CNA generated.

To understand how such an exercise helps us to understand the potential effects of e-cigarette use, recall that, in the after period, we are able to determine whether respondents have tried e-cigarettes before. Therefore, we are able to split the after-period sample into two groups: (1) respondents who have tried e-cigarettes and (2) respondents who have not tried e-cigarettes.[25] Having done so, we then can apply the procedure described earlier to both groups and see if the logit models based on before-period data are better/worse at predicting outcomes within each group.

Table 5 provides another illustrative example. In the first panel, we list smoking predicted probabilities for 10 hypothetical after-period NYTS respondents who have not tried e-cigarettes; the second panel reports smoking predicted probabilities for 10 additional after-period respondents who *have* tried e-cigarettes. Note that our

[25] Up to this point, a "vaper" has been defined as a respondent who used e-cigarettes in the 30 days. Similarly, a respondent is a "smoker" or "chewer" if they have smoked or chewed in the same time frame. Therefore, smokers, chewers, and vapers are comparably defined in the data used to produce Table 2 and Figures 1-4. We maintain the same definitions for "smoker" and "chewer" throughout the paper. However, in the predictive analyses section the term "vaper" is redefined to include any respondent who has *ever* tried e-cigarettes. We make this change because our intention is to examine whether any exposure to e-cigarettes is associated with a heightened risk for smoking or chewing habitually.

predicted probabilities suggest that we would expect to find about 2 smokers in each set of 10 respondents, a prediction that is quite accurate in the first panel. However, there are 7 smokers present in the second panel, about 5 more than predicted by our logit model. In other words, the before-period data does a good job of predicting aggregate smoking behavior for after-period respondents who do not vape, but significantly underestimates the aggregate number of smokers among vapers during the same period.

Table 5. Example of predicting smoking probabilities in after-period data, based on before-period logit models (nonvapers vs. vapers)

ID #	Year	Gender	Age	Grade	Race	Hispanic	Lives with Smoker	P(Smoker)	Smoker
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Panel 1: Have never tried e-cigarettes									
1	2011	male	13	7	black	no	yes	0.13	no
2	2011	male	15	10	white	yes	no	0.21	no
3	2012	female	17	11	asian	no	no	0.16	no
4	2014	female	18	12	asian	no	yes	0.19	no
5	2013	female	18	12	white	no	no	0.2	yes
6	2014	male	11	6	white	no	yes	0.09	no
7	2012	female	14	9	black	no	no	0.17	no
8	2011	male	16	10	white	yes	no	0.25	no
9	2014	male	15	9	white	no	no	0.22	yes
10	2013	female	17	11	white	yes	yes	0.29	no
Sum								1.91	2
Panel 2: Have tried e-cigarettes									
1	2011	female	14	9	white	no	no	0.11	yes
2	2011	male	14	8	white	yes	no	0.16	yes
3	2012	male	16	10	black	no	yes	0.22	yes
4	2014	female	18	12	asian	no	no	0.21	no
5	2013	male	12	7	white	yes	no	0.14	yes
6	2014	female	13	8	asian	no	no	0.13	no
7	2012	female	17	11	black	no	yes	0.29	yes
8	2011	male	18	12	black	no	yes	0.31	yes
9	2014	male	14	9	white	no	yes	0.19	yes
10	2013	female	15	10	white	yes	no	0.17	no
Sum								1.93	7

Source: Hypothetical example is CNA generated.

It cannot be stressed enough that the results depicted in Table 5 have many potential interpretations. One possibility is a link between e-cigarettes and smoking that many researchers have promoted; namely, that e-cigarettes serve as a gateway for traditional cigarette use. In this scenario, our logit model predicts fewer smokers than it should because it fails to account for the positive effect that e-cigarette use has on one's chance of being a smoker. However, another possibility is that e-cigarette use and smoking both are driven by an unobserved factor (or factors) not included in the logit model; in this case, it would be wrong to conclude that e-cigarette use *causes* any change in smoking behavior.

Subject to these important interpretation issues, the procedure just described is aimed directly at answering whether e-cigarettes serve as a gateway drug for using other tobacco products (such as smoking and chewing). A closely related question is whether adolescents who use e-cigarettes would have otherwise been traditional tobacco users, an inquiry that the same logit models may be useful in answering. Consider again column 8 of Table 4, which reports the predicted probability of smoking for 10 hypothetical NYTS respondents interviewed in the after period. These predictions are based on before-period data, which were collected at a time when e-cigarettes were unavailable. Clearly, some of these respondents seem to have a relatively high risk of traditional smoking in the absence of e-cigarettes, while others do not. By examining the correlation between one's predicted probability of smoking and their reported e-cigarette use, we can shed light on whether adolescents who vape are more/less likely to have been traditional smokers in the first place.

Predicting frequency and intensity of cigarette usage

As stated in the introduction, another study motivation is to understand whether e-cigarettes are a substitute or a complement to traditional tobacco use *among traditional tobacco users*. Once again, data from the before period can be helpful, but, in this case, our goal is to predict the frequency and intensity of traditional tobacco use, as opposed to the probability of being a user. In this context, *frequency* is defined as the number of days a respondent has used traditional tobacco products in the past 30 days, while *intensity* is defined as the amount of traditional tobacco products used per day of use.

Of the two traditional tobacco products considered in our research (cigarettes and chewing tobacco), the NYTS has sufficient data to measure frequency and intensity for cigarettes only. This is done using two questions that appear in every NYTS wave:

1. Frequency question: During the past 30 days, on how many days did you smoke cigarettes?

2. Intensity question: During the past 30 days, on the days you smoked, about how many cigarettes did you smoke per day?

In both cases, respondents are asked to select from a set of categories (rather than providing specific counts); for example, a respondent might report smoking 6-9 days in the past 30 days, and that, during those days, he/she smoked 2-5 cigarettes.

For the frequency question, there are seven possible categories:

- 0 day
- 1-2 days
- 3-5 days
- 6-9 days
- 10-19 days
- 20-29 days
- 30 days

Excluding respondents who have not smoked in the past 30 days, there are six possible categories for the intensity question:

- < 1 cigarette
- 1 cigarette
- 2-5 cigarettes
- 6-9 cigarettes
- 10-19 cigarettes
- 20 or more cigarettes

Since frequency and intensity are not binary (i.e., yes/no) outcomes, the logit approach described earlier is not appropriate. Instead, we estimate the probability of these categorical outcomes using a multinomial logit approach, in which the outcome is allowed to be one of several discrete categories. The same variables that we used to predict the probability of being a traditional tobacco user (i.e., survey year, gender, Hispanic ethnicity, race, grade level, being old/young for grade level, and living with a smoker) also are used in our multinomial logit models. Furthermore, the conceptual goal is very similar to what has already been discussed in detail, and it can be summarized by the following procedure:

1. Using NYTS before-period data (i.e., the 2002-2006 waves), estimate multinomial logit models for smoking frequency and intensity.
2. Split the NYTS after-period data (i.e., the 2011-2014 waves) into two groups: those who have not tried e-cigarettes, and those who have.
3. For each of the groups defined in step 2, use the multinomial logit results obtained in step 1 to predict smoking frequency and intensity.

Our ultimate goals are to determine smoking intensity/frequency prediction accuracy for the groups defined in step 2 and to see if intergroup differences in prediction accuracy highlight anything about the relationship between e-cigarette use and smoking intensity/frequency.

Predictive Analysis: Results

Predicting cigarette/chew usage

Table 6 reports the results of the logistic regressions discussed in the methodology section. Recall that each of these models estimates the probability of a binary outcome (e.g., having never smoked or chewed before), based on an NYTS respondent's (1) year of survey, (2) gender, (3) Hispanic ethnicity, (4) race, (5) grade level, and (6) age[26], and (7) cohabitation with someone who smokes traditional cigarettes. All respondents were interviewed in one of three NYTS waves from 2002 to 2006 (for a total of 60,966 observations).

Although the estimated percentage point changes are not a central focus in this study, it is useful to review them briefly. For ease of interpretation, examine the estimated percentage point change of the male variable for each model. We see that being male as opposed to female decreases the likelihood that someone has only smoked in the past 30 days by 4 percentage points, increases the likelihood that someone has only chewed by 3 percentage points, increases the likelihood that someone has done both by 4 percentage points, and decreases the likelihood that someone has not used either in the last 30 days by 2 percentage points. In addition, being male decreases the likelihood that a person has never smoked or chewed by 3 percentage points. In other words, holding all other variables equal, male youth are less likely to have only smoked in the past 30 days, though they are more likely to have chewed or been dual users over the same timeframe. In addition, male youth are less likely to have not smoked or chewed over any time horizon.

The probability of having only smoked in the past 30 days appears to decline as survey year increases, while the probability of having neither smoked nor chewed in the past 30 days (or ever) increases with survey year. In other words, traditional cigarette smoking in the adolescent population seems to have steadily declined with time between 2002 and 2006, even after controlling for the other variables in the model.

[26] More specifically, whether the respondent is old or young relative to his or her grade's modal age.

It is not surprising that grade level has a powerful positive association with smoking and chewing, in part reflecting that older respondents are more likely to have smoked and/or chewed in the past 30 days. However, changes in grade level may also proxy for changes in social environment that affect tobacco use independent of age. For example, moving from 8th grade to 9th grade represents a major environmental change for the vast majority of American adolescents, who go from being the oldest students in a middle school to the youngest students in a high school. The indicators we include for being old or young for one's grade suggest that the older students in every grade level are more likely to smoke and/or chew (relative to students of modal age for their grade); conversely, students who are below modal age are less likely to engage in these activities. A plausible interpretation of this finding is that older students within each grade are more socially mature than their classmates and, consequently, are more apt to engage in adult-oriented behaviors.

Table 6. Estimated percentage point changes in likelihood of using different tobacco products using before-period (2002-2006) data[a]

	In past 30 days…				Never smoked or chewed
	Only smoked	**Only chewed**	**Both**	**Neither**	
	[1]	[2]	[3]	[4]	[5]
Survey Year	-0.01**	0.00003	-0.0003	0.01**	0.02**
Male	-0.04**	0.03**	0.04**	-0.02**	-0.03**
Hispanic	0.01*	-0.01*	0.005	-0.01	-0.05**
Black	-0.06**	-0.02**	-0.02**	0.1**	-0.0004
Asian	-0.08**	-0.03**	-0.01**	0.11**	0.12**
Nat. American	0.005	0.0002	-0.01	0.0003	-0.06**
Pac. Islander	-0.01	-0.01	0.01	0.01	-0.02
7th Grade	0.07**	0.01*	0.01*	-0.08**	-0.12**
8th Grade	0.12**	0.01**	0.01**	-0.13**	-0.21**
9th Grade	0.15**	0.02**	0.02**	-0.18**	-0.28**
10th Grade	0.19**	0.02**	0.03**	-0.22**	-0.36**
11th Grade	0.2**	0.02**	0.03**	-0.24**	-0.41**
12th Grade	0.24**	0.02**	0.04**	-0.29**	-0.49**
Young for Grade	-0.03**	-0.004**	-0.003	0.03**	0.06**
Old for Grade	0.07**	-0.0001	0.02**	-0.09**	-0.14**
Live with Smoker	0.1**	0.003*	0.02**	-0.13**	-0.22**
N	60,966	60,966	60,966	60,966	60,966
AUC	0.74	0.78	0.79	0.74	0.74

Source: CNA-generated table from 2002, 2004, and 2006 NYTS waves.

[a] Significance levels: * = p ≤ 0.05, ** = p ≤ 0.01.

Of interest, our results also suggest that Hispanic respondents are significantly more likely to have only smoked or only chewed in the past 30 days, and they are significantly less likely to have never tried either product. Relative to white respondents, blacks and Asians are less likely to be smokers or chewers, and Native Americans are less likely to have never tried cigarettes or chew.

Finally, the logit models in Table 6 indicate that living with a smoker (i.e., someone who uses traditional cigarettes) has a highly significant positive effect on the probability of any form of tobacco use in the past 30 days. This is an intuitive finding: living with people who smoke is likely to motivate one to engage in the same behavior, especially if those people are role models or authority figures (as would be the case with most American adolescents).

The last row of Table 6 reports area under the ROC curve (AUC) values for each logit model. The AUC measure can take any value between 0 and 1, and is commonly used to express the predictive power (at an individual level) of logit models.[27] An AUC value of 0.5 indicates that a model has no predictive power at all,[28] and values less than 0.5 mean that the model in question has *negative* predictive value.[29] Therefore, a logit model must have an AUC measure greater than 0.5 to be useful in predicting outcomes for individuals, and the nearer to 1 the better. As a rule of thumb, AUC values in the 0.5-0.69 range indicate poor predictive power, those in the 0.70-0.79 range indicate fair (i.e., passable) predictive power, and those ≥ 0.80 indicate good/excellent predictive power.

According to the results in Table 6, all of our before-period logit models have passable in-sample predictive power at an individual level. Undoubtedly, variables identifying geographic location and socioeconomic characteristics would be enormously helpful in predicting whether a particular NYTS respondent is at high/low risk for tobacco use, but the NYTS does not collect these data elements.

Having discussed the before-period logit models, we can now turn to our predictive analyses, which use these estimates to predict behavior in after-period (i.e., 2011-2014) NYTS respondents. Table 7 compares our predictions with actual outcomes for the set of after-period respondents who have never tried e-cigarettes (i.e., nonvapers).

[27] It also has application in logit-like regression models, the probit being a widely used example.

[28] Its use in prediction is equivalent to flipping a coin for the same purpose.

[29] Simply put, using the model for predictive purposes would be worse than flipping a coin.

Table 7. Predicted vs. actual tobacco users in after period (nonvapers)[a]

In past 30 days…	Predicted [1]	Actual [2]	Diff. [3]	% Diff. [4]	AUC [5]
Only smoked	4,516	2,413	-2,103	-46.6	0.75
Only chewed	840	850	10	1.2	0.66
Smoked & chewed	1,271	653	-618	-48.6	0.73
Neither	54,538	57,163	2,625	4.8	0.75
Never smoked or chewed	47,448	48,454	1,006	2.1	0.74
N	61,079				

Source: CNA-generated table from 2011-2014 NYTS waves.

a. All included report having never tried e-cigarettes.

In broad terms, Table 7 makes it clear that our logit models based on 2002-2006 NYTS data overpredict tobacco use among NYTS respondents in the 2011-2014 waves. Specifically, our estimates predict several thousand more traditional cigarette users than actually appear in our after-period data, while our predictions for tobacco chew use are accurate in the aggregate. These findings are not surprising; cigarette use has been declining for years among American adolescents, and the simple linear time trend included in our logit model cannot account for the fact that this decline has been more rapid in recent times (relative to the 2002-2006 period). The AUC values reported in column 5 suggest that the predictive power of our before-period logit models is mostly passable for after-period nonvapers; a notable exception is the model for "only chewers," which has a relatively poor AUC of 0.66.[30]

Given the overestimation of cigarette use seen among nonvapers in our after-period data, the results reported in Table 8 are striking. In this table, we have limited the sample to include only after-period respondents who have tried e-cigarettes before (i.e., vapers). Instead of overestimating tobacco use among these people, we find that the same logit models dramatically *underestimate* the number of smokers and chewers among the set of vapers in our sample. For instance, of the 6,352 after-period respondents who report having ever tried e-cigarettes, our logit estimates suggest that 790 of them should have smoked (but not chewed) in the past 30 days. In fact, we find 1,814 respondents of this kind, a number well over twice what we

[30] This finding further highlights the difference between predictive value at the aggregate and individual levels. Having only chewed tobacco in the past 30 days is relatively rare, making it hard to accurately predict at the individual level. Even so, in the aggregate, the same model does a good job of predicting the total number of only chewers.

would expect. Our logit models perform even worse at predicting the use of chew among people who have tried e-cigarettes, and they are especially bad at predicting the number who have smoked and chewed in the past 30 days (221 predicted vs. 777 actual). Finally, the AUC values for all of these models indicate poor or even useless predictive power at an individual level.

Table 8. Predicted vs. actual tobacco users in after period (vapers)[a]

In past 30 days...	Predicted [1]	Actual [2]	Diff. [3]	% Diff. [4]	AUC [5]
Only smoked	791	1,814	1,023	129	0.63
Only chewed	119	329	210	177	0.45
Smoked & chewed	221	777	556	252	0.57
Neither	5,218	3,432	-1,786	-34	0.67
Never smoked or chewed	4,260	1,277	-2,983	-70	0.68
N	6,352				

Source: CNA-generated table from 2011-2014 NYTS waves.

[a] All report having tried e-cigarettes at least once.

Comparing Tables 7 and 8 raises two questions: (1) why do our logit models based on 2002-2006 NYTS data overestimate aggregate cigarette use among nonvapers in the after period but underestimate aggregate cigarette and chew use among vapers in the same timeframe? and (2) why do the models for vapers in the after period have so little predictive power relative to their nonvaper counterparts? One explanation is that e-cigarettes serve as a gateway drug to traditional tobacco use and that e-cigarette users are more prone to smoking and/or chewing than their other characteristics would suggest. This is a tempting conclusion, but alternative explanations exist. For example, there may be unobserved factors that simultaneously increase vaping and traditional tobacco use; since we cannot control for such factors in our logit models, we end up underestimating smoking and chewing among vapers. Although issues such as these ultimately prevent us from making any definitive causal statements, the findings presented in Tables 7 and 8 strongly suggest that the gateway effects of e-cigarette use should be the focus of future research efforts.

Although Tables 7 and 8 provide some indication that e-cigarettes serve as a gateway to traditional tobacco use, this finding does not shed any light on another central study question: are e-cigarettes primarily adopted by traditional tobacco users, or has vaping become popular among adolescents who otherwise would have been unlikely to use tobacco products? Table 9 examines this issue directly, by comparing after-period respondents' predicted risk of smoking or chewing with their observed

use of e-cigarettes. The pattern is clear: respondents with a higher risk of smoking and/or chewing (based on our 2002-2006 logit model) are more likely to report having ever tried e-cigarettes. In other words, these findings support the conclusion that youth e-cigarette use is concentrated among those who were already at relatively high risk of being smokers/chewers.

Table 9. Predicted probability of smoking/chewing and observed vaping behavior in after-period respondents

P(smoker or chewer)	% Vapers	N
	[1]	[2]
≤ 5%	3	20,171
(5%,10%]	6.7	17,771
(10%,15%]	11.4	11,945
(15%,20%]	14.3	6,928
(20%,25%]	16.1	3,936
> 25%	23.6	6,680
All	9.4	67,431

Source: CNA-generated table from 2011-2014 NYTS waves.

Despite this, note that a substantial minority of vapers are those whom we predict to be at low risk for tobacco use in the absence of e-cigarettes (i.e., based on our 2002-2006 NYTS data). In fact, roughly 9.5 percent of vapers (601 out of 6,352) in our after-period data have a predicted probability of smoking and/or chewing of no more than 5 percent, and about 28.3 percent of vapers have a predicted probability of no more than 10 percent. As such, we find some evidence to suggest that a minority of the adolescent vaping population is composed of those who have a low baseline risk for smoking or chewing.

Predicting frequency and intensity of cigarette use

The final research question motivating this study is whether e-cigarettes substitute for or are a complement to traditional tobacco use. Given limitations in the NYTS survey, this subsection will focus on the substitutability/complementarity of vaping and smoking traditional cigarettes.

As discussed in the methodology section, the NYTS data allow us to measure traditional cigarette consumption in two ways: by frequency (i.e., the number of days

one has smoked in the past 30 days) and by intensity (i.e., the average number of cigarettes smoked per day on days that one has smoked). By estimating multinomial logit models with our before-period NYTS data, we can predict both frequency and intensity of smoking among respondents in our after-period sample.

As before, we split the after-period sample into two groups: respondents who have never vaped, and those who have. In Table 10, we report predicted and actual smoking frequency for the former group.

Table 10. Predicted vs. actual smoking frequency in after period (nonvapers)[a]

Days smoked in past 30 days	Predicted [1]	Actual [2]	Diff. [3]	% Diff. [4]
0 days	55,160	58,013	2,853	4.9
1-2 days	1,749	1,231	-518	-42.1
3-5 days	1,152	478	-674	-141
6-9 days	510	301	-209	-69.4
10-19 days	716	330	-386	-117
20-29 days	671	239	-432	-180.8
All 30 days	1,120	487	-633	-130
N	61,079			

Source: CNA-generated table from 2011-2014 NYTS waves.

[a]. All included report having never tried e-cigarettes.

The patterns we see in Table 10 suggest that our before-period multinomial logit model overestimates smoking frequency among after-period nonvapers and underestimates the fraction of this population that has not smoked in the past 30 days. Similar to the results reported in Table 7, it seems reasonable to assume that the patterns observed in Table 10 reflect the inability of our 2002-2006 data to capture the more rapid recent decline in cigarette use among American adolescents.

Table 11 reports the predicted and actual cigarette use frequency among after-period respondents who have tried e-cigarettes. Among this group, we see patterns that are diametrically opposed to those seen in Table 10. Specifically, our multinomial logit model significantly overestimates the number of people who have not smoked in the past 30 days, and underestimates cigarette use frequency at all levels. Simply put, vapers in our after-period data use traditional cigarettes far more often than we would guess based on our 2002-2006 estimates.

The second measure of cigarette consumption available to us is intensity, or the average number of cigarettes smoked per day on days during which smoking occurs.

When considering smoking intensity, we limit our attention to after-period NYTS respondents who report having smoked at some point in the past 30 days.

Table 11. Predicted vs. actual smoking frequency in after period (vapers)[a]

Days smoked in past 30 days	Predicted [1]	Actual [2]	Diff. [3]	% Diff. [4]
0 days	5,334	3,761	-1,573	-41.8
1-2 days	247	652	405	62.1
3-5 days	188	312	124	39.7
6-9 days	83	235	152	64.7
10-19 days	119	323	204	63.2
20-29 days	129	307	178	58
All 30 days	250	762	512	67.2
N	6,352			

Source: CNA-generated table from 2011-2014 NYTS waves.

[a.] All report having tried e-cigarettes at least once.

Table 12. Predicted vs. actual smoking intensity in after period (nonvapers)[a]

Cigarettes smoked per day	Predicted [1]	Actual [2]	Diff. [3]	% Diff. [4]
< 1 cig/day	819	789	-30	-3.8
1 cig/day	554	701	147	21
2-5 cigs/day	1,098	1,113	15	1.3
6-10 cigs/day	311	241	-70	-29
11-20 cigs/day	138	104	-34	-32.7
> 20 cigs/day	147	118	-29	-24.6
N	3,066			

Source: CNA-generated table from 2011-2014 NYTS waves.

[a.] All included report having smoked at least once in the past 30 days, and they have never tried e-cigarettes.

Table 12 reports our results for the set of after-period respondents who have never tried e-cigarettes. In general, these findings suggest that nonvapers who report having smoked at some point in the past 30 days smoke less than we would expect based on our before-period multinomial logit models. In particular, our estimates

underestimate the number of nonvapers who only smoke one cigarette per day smoked and significantly overestimate the number of nonvapers who smoke more than five cigarettes per day smoked. Taken together with Table 10, it appears that nonvapers in our after-period data (1) are less frequent smokers than we would expect based on before-period estimates and that (2) even when they do report having smoked in the past 30 days, they smoke less per day than expected.

Table 13. Predicted vs. actual smoking intensity in after period (vapers)[a]

Cigarettes smoked per day	Predicted [1]	Actual [2]	Diff. [3]	% Diff. [4]
< 1 cig/day	623	429	-194	-45.2
1 cig/day	450	484	34	7
2-5 cigs/day	969	1,049	80	7.6
6-10 cigs/day	299	344	45	13.1
11-20 cigs/day	139	154	15	9.7
> 20 cigs/day	111	131	20	15.3
N	2,591			

Source: CNA-generated table from 2011-2014 NYTS waves.

a. All included report having smoked at least once in the past 30 days and having tried e-cigarettes at least once.

Table 13 is the counterpart to Table 12 for respondents who report having tried e-cigarettes. Just as was the case for smoking frequency, the differences between vapers and nonvapers with respect to smoking intensity is striking. Specifically, our predictions based on before-period data dramatically overestimate the number of very low intensity (i.e., < 1 cigarette per day smoked) smokers among the vaping population, and underestimate the number of smokers at all other intensity levels. In summary, Tables 11 and 13 suggest that (1) vapers use traditional cigarettes far more frequently than we would expect and that (2) when they do smoke, they smoke more intensively than our 2002-2006 data would predict.

Conclusions and Recommendations

As expected, the NYTS data indicate that traditional cigarette use among American adolescents has dropped precipitously in recent years, from 17 percent in 2002 to just 4 percent in 2014. Chew also has been tracked in all NYTS waves, with its use remaining relatively constant over the period (5 percent in 2002 vs. 4 percent in 2014). Although e-cigarette questions have only been asked since 2011, the data available indicate that vaping is rapidly expanding among American adolescents. In fact, although only 1 percent of respondents reported using e-cigarettes in 2011, about 9 percent did so in 2014 (a ninefold increase).

The summary statistics we generate provide a snapshot of the vaping population and give us a sense of how these adolescents differ from traditional smokers, chewers, and nonusers. For example, we find that vapers are much older than nonusers, but they are also slightly younger than NYTS respondents who report traditional cigarette and/or chew use. Vapers are also more likely to be female, white, and Hispanic in comparison with nonusers, and they are far more likely than nonusers to live with someone who smokes traditional cigarettes.[31]

Our predictive analyses reveal a number of interesting results. First, we find that e-cigarette use is more common among 2011-2014 NYTS respondents who we predict will have a relatively high risk of smoking and/or chewing (based on before-period data); in other words, adolescents who vape seem to be drawn disproportionately from the population of youth who are more likely to use traditional tobacco products in the first place. Having said this, we do find that a minority of vapers in the NYTS data are adolescents with a relatively low chance of using traditional tobacco products. This latter finding suggests that vaping may be spreading to parts of the youth population that would otherwise have very low exposure to tobacco products.

The logit and multinomial logit models we estimate (using before-period data) also perform quite differently when making out-of-sample predictions for vapers and nonvapers during the 2011-2014 period. In the latter case, our logit models substantially overestimate the number of traditional smokers among nonvapers. Furthermore, we predict that nonvapers smoke traditional cigarettes more frequently

[31] All of the differences discussed here are statistically significant at the 5-percent level.

(i.e., on more days) and more intensely (i.e., more cigarettes per day) than is actually the case. These overestimates reflect the fact that traditional smoking has declined more rapidly among American adolescents in the last half-decade or so, and our regression models are based on data from a period (2002-2006) that predates this accelerated decline.

Given that our before-period logit and multinomial logit models fail to capture the relatively more rapid decline in traditional smoking that we see in the post-2006 period, it is especially surprising that the same models *underestimate* traditional cigarette use among vapers in the 2011-2014 period. In fact, 2,920 (46 percent) of the vapers in our after-period data used traditional cigarettes and/or chew at least once in the 30 days leading up to their interview, more than 2.5 times the predicted number (1,134). Furthermore, our multinomial logit models substantially underestimate smoking frequency and intensity among vapers.

Since e-cigarette use is not randomly assigned among NYTS respondents, attaching a definitive causal interpretation to any of these results is premature. Yet, the results lend weight to the suggestion that adolescent e-cigarette use is concentrated among those who would have been at relatively high risk for tobacco use in the absence of e-cigarettes; however, the results also make clear that a minority of adolescent vapers would have otherwise been at low risk for tobacco use. In this sense, e-cigarette use does appear to have spread somewhat among American adolescents who would otherwise have not been likely to use tobacco products.

The other results are more difficult to interpret in the absence of a robust identification strategy. One possibility is that vaping provides an addiction gateway that encourages traditional tobacco use, making e-cigarette users more likely to smoke and/or chew than we would otherwise expect. Furthermore, it could be that e-cigarettes and traditional cigarettes are complements and that adolescent vapers smoke normal cigarettes more frequently and with greater intensity than they would if e-cigarettes were not available. If true, these conclusions suggest that e-cigarettes could have a particularly damaging effect on the population of potential military recruits, though these effects would be concentrated among those who were already at relatively high risk for tobacco use.

Although conclusions like those given above are tempting, we cannot rule out alternative explanations due to current data limitations. For example, it is possible that unobserved factors[32] are simultaneously driving e-cigarette use and traditional

[32] For example, an individual's attitude toward risk may be a key factor in determining uptake of all kinds of tobacco products (including e-cigarettes). It is not impossible to measure risk aversion (in fact, it is quite common in some areas of research), but to date the NYTS has made no attempt to do this formally.

tobacco use, so that vaping itself has no *causal* impact on traditional tobacco use. Obtaining causal evidence for the relationship between e-cigarettes and other tobacco products will require an identification strategy in which e-cigarette use randomly varies across the adolescent population (e.g., through a randomized control trial design, or as the result of regulations).

With this in mind, the study's results motivate a number of recommendations for improving DOD's understanding of effects associated with e-cigarette use in the recruitable population. First and foremost, it is imperative that more be done to measure tobacco usage in general (and e-cigarette use in particular) among new recruits. DD Form 2807-2 is completed by all potential recruits during MEPS processing, and—in past versions—a four-part question about tobacco use was included (see Figure 6).

Figure 6. Smoking question on DD Form 2807-2

							Yes	No
(73) Do you smoke? *(If yes:)*								
(a) Type		Cigarettes		Cigars		Smokeless tobacco		
(b) How many per day?			(c) Date last used					

Source: DD Form 2807-2 (version approved August 2011, expired August 31, 2014).

This question ascertains (1) whether recruits smoke, (2) what type of smoking activity they engage in, (3) how many times per day they smoke, and (4) when they last smoked. Unfortunately, this item does not appear in the most recent version of the form (which was approved in March 2015); as such, we are unaware if DOD currently collects data on tobacco use among new recruits.

Should DOD wish to understand the effects of tobacco use (both traditional tobacco products and e-cigarettes) on the recruitable population, collecting data on new recruits is an excellent first step. New recruits are a valuable asset in this regard because (1) DOD already has well-established procedures for collecting new recruit data, and (2) the behavior of new recruits is likely to be highly correlated with that of the recruitable population in general. Consequently, we recommend that the question depicted in Figure 6 be restored to DD Form 2807-2, together with a similarly formatted question regarding e-cigarette use. Similarly, we encourage DOD to explore options for tracking tobacco use among all existing servicemembers on a routine basis. Such an effort would facilitate research aimed at understanding how tobacco use evolves over time for servicemembers and how that use might affect job performance and military readiness.

This study also highlights the need to closely track the evolution of e-cigarette regulations over time, for several reasons. Recent evidence (e.g., new e-cigarette regulations by the FDA) suggests that regulatory activity pertaining to e-cigarettes will increase significantly in the near future. Tracking these regulations will give DOD a sense of how various state/local governments and other organizations are managing e-cigarettes. Furthermore, regulatory changes may offer opportunities for research in which the effect of e-cigarette use can be convincingly measured.

Finally, we recommend that DOD look for opportunities to disseminate educational materials with regard to e-cigarette use, both to existing servicemembers and to the recruitable population. Our review of the literature makes clear that the potential health effects of vaping are poorly understood by many people and that this lack of knowledge may lead to suboptimal decision-making. In particular, we find it troubling that many adolescent vapers *think* that they are using flavor-only liquids that do not contain nicotine [12], even though these products often contain trace amounts of the addictive chemical [13]. Improving education is likely to play a crucial role in maintaining adolescent health, and it is in DOD's interest to play a leading role in this regard.

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